EXECUTIVE SUMMARY

0.1 BACKGROUND

Bangalore metropolitan area covers 137 zones of the City Corporation area and the remaining 22 Zones are in Urban Municipalities covering an area of about 531 sqkm.

Population of Bangalore city, as per 2001 census, is 5.67 million out of which 4.5 million is in the city Municipal Corporation area. Bangalore at present has more than 1.6 million registered vehicles out of which 1.2 million are two-wheelers constituting 75% of the total registered vehicles. The total vehicle population is increasing at the rate of 10% per annum, while the two-wheelers alone are increasing at 17% per annum.

BMTC buses are the main mode of public transport in Bangalore city. BMTC has a fleet of about 2450 buses, which carry about 22.28 lakh trips per day, while other buses (Factory buses/Chartered buses, etc.) carry about 1.65 lakh trips per day. The other major mode of public transport is auto - rickshaw which carry about 2.2 lakh trips per day.

Transport Problems

Like any other metropolitan city in India, Bangalore also faces many transport problems. Low travel speed, high accident rate involving fatalities and increased vehicular pollution are mainly due to:

- Narrow roads with heavy traffic congestion;
- Little possibility of expansion of road network due to heavily built-up areas;
- Frequent traffic jams at numerous road intersections;
- 75% of composition of traffic consisting of low occupancy vehicles, viz. two-wheelers;
- Very high number of auto rikshaws;
- High parking demand due to proliferation of personalised vehicles; and
- Over-crowded buses with long routes.

Need for an efficient rail-based system has been felt for a long time and numerous studies were carried out in the past. A serious attempt to implement an ELRTS system was also made with private participation in the recent past.

Previous Studies

These include a study carried out by the Central Road Research Institute in 1963 for improving the road network and traffic management system and it proposed a rail network of 26 km. In 1982 a Government Study Group proposed a metro system along with suggestions for improvement of transport system in the city through grade separators.
The Metropolitan Transport Project, an organisation of Indian Railways, prepared a feasibility report in 1983 for provision of suburban services on

existing lines, a ring railway and a rapid rail transit system on two corridors. The estimated project cost for these works, at 1983 price level, was Rs. 650 crores, with a suggested completion period of 25 years.
In the year 1988 a World Bank aided study for Bangalore Urban Transport Project (BUTP) carried out by RITES recommended a suburban rail system along with improvement of road transport system.
The first Mass Rapid Transport System was recommended in 1993, based on the 1983 report, by an official committee nominated by the State Government. The work was to be carried out in two phases:

Phase I

- MRTS from Rajaji Nagar to Jaya Nagar (12.9 km - partly underground)
- Suburban corridor on existing rail network

Phase II

- MRTS from Hudson Circle to Krishnarajapuram (11.2 km)
- Circular railway for 57.9 km

Bangalore Mass Rapid Transport limited (BMRTL) was incorporated in 1994 by the State Government to implement the Mass Rapid Transport System. BMRTL, in turn, asked IL&FS to carry out a feasibility study for an LRT system on Public - Private Partnership basis. The main recommendations of the study were:

- An elevated LRT system on 6 routes, viz:

  - Yeshwantapur to Kanakpura via Rajaji Nagar and Jayanagar;
  - Hudson junction to Indira Nagar via M G Road and Airport;
  - Yeshwantapur to Mayo Hall via Mekhri junction;
  - Jayanagar to Mayo Hall via Koramangala;
  - Chord road to Kanakpura via Banashankari; and
  - Ulsoor to Mekhri Circle and Hebbal;

- Traffic forecasts were made for the year 2001 and 2011;
- Recommended a fare of Rs. 0.55 per pkm (1994 prices);
- Capacity of the system as 24,850 peak hour peak direction trips(phpdt);
- Train headway varying from 5.45 mts to 30 mts on different sections;
- Special rolling stock with 750 Volt dc traction system;
- Total construction period 7.5 years from 1st April 1999;
- Total cost of the project as Rs. 2025 crores (excluding land) at 1994 prices; and
- FIRR projected as 12.9% (upto 2030)

However the project could not take off for various reasons, despite fixing up a private partner for implementation of the project.
While the implementation of the ELRTS project was delayed due to various reasons, traffic snarls on the city roads continued to go from bad to worse. In such a scenario the State Government asked DMRC to step in and propose a metro system on two busy corridors for implementation as a fast track project more or less on similar lines as the Delhi Metro.

DMRC, after numerous site visits, detailed reconnaissance and study of past reports including the traffic pattern recommended two corridors, viz. An East - West corridor and a North - South corridor.
The East - West corridor starts at Baiyappanahalli and traverses through Indira Nagar, CMH Road, Swamy Vivekanand Road, M G Road, Ambedkar Road, Post Office Road, K G Road, Majestic, KSRTC bus stand, Bangalore city Railway station, Magadi Road, Toll Gate junction, Chord road, Vijay Nagar and Mysore road upto Ring Road junction.

The North - South corridor starts form Yeshwantapur in the North and passes through Chord Road, Mahakavi Kuvempu Road, Swastik, Platform Road, KSRTC bus stand, Chickpete, City Market, K R road, Vanivilas Road, Lal Bagh, Southend circle and R V road upto J P Nagar.

The two lines cross each other at Majestic, close to the City Railway station, where a rake interchange line connecting the two corridors has also been proposed.

These corridors mostly cover the two priority corridors of the earlier ELRTS system but with provision of underground sections in Central Business District (CBD) area which were avoided in the ELRTS corridors. Thus the recommended corridors are reduced in length as compared to the ELRTS corridors and at the same time will serve the most congested area of the city (Central Business District) without which the success of such a system would have been in doubt. The selection of the corridors is also justified by the traffic demand forecast. The corridors selected were got approved in principle by the State Government before detailed surveys were undertaken.

0.2 TRAFFIC DEMAND

Estimation of traffic demand on the two corridors of Bangalore Metro has been done based on primary surveys. Following primary surveys were carried out between November 2002 and January 2003:

- Household survey (10000 samples - about 1% of house holds)
- Bus terminal and Bus stop survey (1200 bus stops, 43 terminals)
- Classified traffic volume survey along with O - D Survey at outer cordon (10 locations)
- Classified traffic volume survey at screen line and mid block (40 locations)
- Speed and Delay survey along major corridors (660 kms)
- Road network inventory for all major roads (320 km)

Trip Information

Total no. of trips performed in the city are about 58.52 lakhs. This includes walk and cycle trips. Out of these vehicular trips are 48.74 lakhs.

Purposewise Distribution of Trips

The distribution of trips by "purpose" is presented in the table below

Purpose	% Trips
Work	53
Education	22
Others	25
Total	**100**

Per Capita Trip Rate (PCTR)

The per capita trip rate excluding walk trips was observed to be 0.82.

Opinion Survey

Results of the Opinion survey are summarised below

- 48% of the commuters are willing to shift to Metro if walking distance to the station is upto 250 meters, 38.84% of the commuters are ready to shift to Metro with a walking distance of 500 meters.
- 65% of the commuters prefer only one interchange, 30% accept two interchanges while the rest accept more than two interchanges.
- 89% of the commuters are ready to shift with feeder bus services.
- 46.18% of the commuters prefer 5 minute frequency, 32.16 % accept frequency upto 10 minutes and rest 15 minutes.
- 88% of the commuters prefer monthly passes.
- 80% of the commuters are willing to pay parking fee at the stations.

Travel Demand Forecast

Four-stage transport demand forecasting method was used to carryout the transport demand forecasts. Land-use parameters used for the purpose are:

a. Base year population 2001 and employment and their distribution have been taken from the 2001 census.

b. Future population and employment for the horizon years 2011 and 2021 have been worked out in consultation with BDA at city level.

c. Distribution of future population and employment at zonal level are based on land use plan in consultation with BDA.

Trip End Models

Taking into consideration the past trends and possibility of accelerated growth rate when the mobility level in the city will increase due to introduction of MRTS, the PCTR for the horizon years have been assessed as follows:

Year	PCTR
2002 (Observed)	0.82
2011 (Forecast)	0.90
2021 (Forecast)	1.00

The above-mentioned PCTRs have been used for development of trip generation and projection.

Trip Assignment

Capacity restrained assignment technique was used for traffic assignment on the transport network. Distribution of the public transport trips between bus and rail has been determined at the assignment stage by considering a combined public transport network and assigning time penalties for various interchanges with other modes. A penalty of 8 minutes has been taken for transfer and waiting time of passengers has been taken as half the headway between the trains.

Traffic assignment was carried out on the selected East - West and North - South Metro corridors along with total transport network of the city. Based on the final assignment of traffic on the total network, loading on the proposed Metro corridors is as follows:

Summary of transport demand projections

Year	Number of passengers (Lakhs/day)	Passenger – km/km of corridor (lakhs/day)	Mean trip length(km)
2007	8.2	1,78,839	6.89
2011	10.2	2,28,201	7.07
2021	16.1	3,62,828	7.12

The maximum range of phpdt (peak hour peak direction trips) on the system by 2007 will be 20,000, and increases to 40,000 by 2021.

0.3 PLANNING AND DESIGN PARAMETERS

DMRC is already implementing Phase I of Delhi Metro project. Various design norms and parameters have been firmed up by DMRC after detailed studies of norms followed by Metro systems in various countries. However, Delhi being a much bigger Metropolitan City than Bangalore, its needs are different. Passenger carrying capacity required for Delhi Metro system is almost double to that of Bangalore Metro system. However a similar system is proposed for adoption for Bangalore city although with reduced capacity. Certain modifications to the design norms have been recommended keeping in view the specific needs of Bangalore city and with an idea of standardisation of parameters for other metropolitan and major cities in the country (with the exception of Mumbai and Delhi).

For the elevated section of Bangalore Metro a 'U' shaped deck as adopted for Line No. 3 of Delhi Metro has been recommended with overall top width of 9 m

(track center 3.7 m to 4.0 m) to carry both the tracks. The section has a walkway at the floor level of the coach for emergency evacuation of passengers. For the underground section a tunnel of 5.2 m internal diameter has been proposed for each track which also includes a footpath. A 15 t axle load has been selected for Bangalore as against 17 t for Delhi.

Bangalore Metro system will have modern, lightweight rolling stock made of stainless steel. Trains are proposed to be air-conditioned, consisting of 3 coaches initially and 6 coaches in future. Maximum acceleration (1.0 m/sec^2) and maximum deceleration (1.1 m/sec^2) parameters are similar to that of Delhi Metro system.
The system is proposed to have Standard Gauge tracks as this will facilitate provision of sharp curves with radii upto 120 m. Other geometrical parameters are similar to that of Delhi Metro system.

It is proposed to provide 750 V dc, third rail traction system for Bangalore Metro in place of 25 kV ac overhead traction system planned for Delhi. The other systems like Signalling with Automatic Train Control and Protection system, Automatic Fare Collection system and tunnel ventilation, etc. are more or less similar to that of Delhi Metro system.

0.4 ROUTE ALIGNMENT

The route alignment has been chosen to serve high population density areas of the city with connectivity to the heart of the city where the Central Business District and the seat of the Government are located and has been suitably integrated with the existing Railway and Bus systems.

The Northern and Western parts of the city are having undulating topography and thus the existing road gradients are steep and have many curves. As the elevated corridors follow the median of the existing roads at most of the locations, the proposed gradients along the alignment are also steep on the Northern and the Western sections. The steepest gradient between stations is 4%. A minimum gradient of 0.3% has been proposed for the purpose of drainage. However stations are to be kept on level.

About 40 % of the route is on curves (including transition curves). Minimum radius of curve on elevated section is 120 m to reduce property acquisition. However minimum radius of 300 m is adopted in underground sections to facilitate working of tunnel boring machines. Stations are provided on straight stretch, as far as possible. However some stations are provided on curves but limiting the radius to 1000 m so that the gap between the train and the platform is kept within the prescribed dimension.

Most of the alignment is kept as elevated to minimise land acquisition and its cost Length of underground sections is restricted to congested areas where elevated construction is not feasible.

On the East - West corridor the elevated stretches are from Mysore Road terminal to Magadi Road - Tank Bund Road junction near Subhash Nagar and from Chinnaswamy stadium to Baiyappanahalli station. The underground

stretch is from Subhash Nagar to the end of Cubbon Park. Baiyappanahalli station is on the surface.

On the North - South corridor, the elevated stretches are from Yeshwantapur to Swastik and from K R road to R V Road terminal. Swastik station is at - grade while the underground stretch is from Swastik to City Market station.
The break-up of route length for the elevated and the underground sections is given below:

Corridor	Total Length	Elevated Length	Underground length	%of length on curves
East – West	18.1 km	14.7 km	3.4 km	44.30%
North – South	14.9 km	11.6 km	3.3 km	39.70%
Rake inter-change line	0.35 km	-	0.35 km	100%

Both the corridors have been planned with possibility of future extensions at all the four ends without any modification.

0.5 STATION PLANNING AND TRAFFIC INTEGRATION

The basic planning for stations, as developed for Delhi Metro over the last five years, has been used to plan the stations for Bangalore Metro also. However the size of stations for Bangalore Metro is smaller than that of Delhi. Stations have been designed to fit in existing road width as far as possible.

Eighteen stations are planned on the East - West corridor out of which 4 are underground and 1 is on the surface. On the North - South corridor 14 stations are planned out of which 3 are underground and 1 is on surface. The remaining stations on both the corridors are elevated. Stations located on the middle of the road have been designed with elevated concourse with access from both sides of the road.

All the elevated stations are provided with side platforms while the underground stations are provided with island platforms. This has been planned to facilitate continuous construction of elevated section carrying two tracks and to avoid reverse curves on the approaches of the stations. For the underground sections Tunnel Boring Machines (TBMs) work effectively with tunnel centers equivalent to two times the tunnel diameter thus providing sufficient space for platform in between. All the underground stations will be constructed by cut and cover method.

Majestic station located in the KSRTC bus stand area is common to both the corridors and is an interchange station. A link line between the two corridors is also provided at this station for transfer of rakes.

The average inter-station distance along the corridors is 1 km, with minimum distance being 0.676 Km, and maximum being 2.04 Km.

Stations have been divided into two distinct areas, namely public and non-public (technical areas). The public area is further sub divided into unpaid and paid area. Provision for escalators are made at all stations in paid area for future. However at a few important stations escalators shall be provided from the beginning itself. Lifts for disabled passengers are provided at all stations except at Baiyappanahalli where ramps are provided.

Road traffic integration facilities are provided at five stations on the East - West corridor, viz. Mysore road terminal. Hoshalli, Bangalore city metro station, Majestic and Ulsoor. On the North – South corridor integration facilities are provided at Yeshwantapur, Swastik, Majestic, City Market and R V Road terminal. Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate parking areas for various modes likely to come to important stations including feeder buses/mini buses. Provision has been made for peak hour demand. Further integration with the railway network is planned at Bangalore City and Baiyappanahalli on the East - West corridor and at Yeshwantapur on the North - South corridor.

0.6 TRAIN OPERATION PLAN

Any public transport system, particularly a Metro system, is made attractive by providing high frequency service both during peak and off-peak hours. For this purpose short trains (3 coach consist) are proposed initially at 4 to 5 minutes frequency during peak periods and 15 minutes frequency during slack periods of the day. The frequency can be brought down to 3 minutes in future depending upon the demand.
Salient features of the proposed train operation plan are:

- Running of services for 19 hours of the day (5 AM to midnight) with a station dwell time of 20/30 seconds.
- Make up time of 5-10%, with 8-12% coasting.
- Scheduled speeds of 32 to 35 kmph.

For the purpose of planning, the peak hour peak direction trips (phpdt) demands for different years are indicated below:

Peak hour peak direction trips

LINE	YEAR		
	2007	2011	2021
Line 1 (E-W)	22,442	27,358	39,838
Line 2 (N-S)	19,585	22,705	31,694

Each 3-coach train will consist of two driving motor coaches (DMC) and a trailer coach (TC), while 6 coach train will consist of 2 DMCs, 2 MCs (motor coaches) and 2 TCs. The capacity of each coach and trains is given below:

DMC : 322 passengers, MC and TC : 356 passengers
3-Car Train : 1000 passengers , 6 Car Train : 2068 passengers

Train operation plan (headway and train composition) for the year 2007, 2011 and 2021 during the peak hours is given below. For the train operation plan during lean hours, details are given in chapter 3 of the Report.

Year 2007

3-car trains at 4 minutes headway are planned during the first year of operation, i.e. 2007. The 3-coach train capacity with 4-min headway is 15000 passengers/hour/direction. This optimum capacity may cause slight over-crowding for short durations on some sections, but will avoid excessive under-loading on the remaining sections.

Year 2011

The train operation on the East – West Corridor is planned with 6-coach trains at 4 minutes headway in 2011 with a capacity of 31,020 passengers. On the North South corridor 3-car train at 4 minutes headway continues in 2011. The capacity of15000 passengers/hour/direction may slightly cause over-crowding on some sections, but will avoid excessive under-loading on the remaining sections.

Year 2021

For the year 2021 train operation on the East – West corridor is planned with 6-coach trains at 3 minutes headway with a capacity of 41,360 phpdt. The planned capacity is more than the peak demand. Train operation on the North South corridor is planned with 6-coach trains at 4 minutes headway in 2021 with a capacity of 31020 phpdt.
Details of capacity provided is summarised below:

(I) EAST – WEST CORRIDOR

Item	2007	2011	2021
coaches/train	3	6	6
Head-way (minutes)	4	4	3
phpdt	15,000	31,020	41,360

(II) NORTH - SOUTH CORRIDOR

Item	2007	2011	2021
coaches /train	3	3	6
Head-way (minutes)	4	4	4
phpdt	15,000	15,000	31,020

0.7 ROLLING STOCK

Rolling stock for Bangalore Metro has been selected based on the following criteria:

- Proven equipment with high reliability;
- Passenger safety features, including fire resistance;
- Energy efficiency;
- Light weight equipment and coach body;
- Optimised scheduled speed;
- Aesthetically pleasing Interior and Exterior;

- Low life cycle cost; and
- Flexibility to meet increase in traffic demand.

The controlling criteria are reliability, low energy consumption, light weight and high efficiency leading to lower annualized cost of service. The coach should have high rate of acceleration and deceleration.
Keeping the above features in mind, 2.88 m wide stainless steel light weight coaches are proposed for the Bangalore Metro, with length of 20.8 m for trailer coach and 21.05 m for motor coach. Height of coach is 3.8 m. Train length for 3 coach train is 64.1 m while that of 6 - coach train is 128 m. The Axle load is about 15 t for which the structures are to be designed.
Traction motors are 180 KW and propulsion system is 3-phase drive with variable voltage and variable frequency (VVVF) control. Trains will have regenerative braking system to save energy cost. Current collection is through bottom collection from third rail at 750 Volt dc. Trains will be air-conditioned and provided with automatic door closing and opening system. The trains will have state of the art cab signalling with continuous automatic train control and automatic train protection system. The trains will have passenger information and announcement system.
Coaches have longitudinal seats with a seating capacity of 50 per coach and total dense crush capacity of 322 (MC) to 356 (TC), at 8 persons/sqm.

No. of Coaches required
The of coaches required in the year 2007, 2011, 2021 are also given below. These includes operation and maintenance reserve.

	2007	**2011**	**2021**
E-W Corridor	63	126	162
N-S Corridor	54	54	108
Total	117	180	270

0.8 POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF

Power Supply System

Electricity is the only source of energy for operation of Metro system – for running trains, for station services, workshops, depots & other maintenance infrastructure. Broad estimation of auxiliary and traction power demand has been made based on the following requirements:-

- Specific energy consumption of rolling stock – 70KWh/1000 GTKM
- Regeneration by rolling stock – 20%
- Elevated/at –grade station load – initially 250KW and finally 300 KW in the year 2021
- Underground station load – initially 1250KW and finally 1750 KW in the year 2021
- Depot auxiliary load - initially 2000KW and finally 2500 KW in the year 2021

Keeping in view the train operation plan, power requirements have been worked out for the year 2007, 2011 and 2021 which are briefly summarized below:-

Power Demand Estimation (MVA)

Corridor		Year		
		2007	2011	2021
E-W corridor	Traction	5	11	14
	Auxiliary	13	15	17
	Total	18	26	31
N-S corridor	Traction	4	4	9
	Auxiliary	11	12	13
	Total	15	16	22

Metro systems require a very high level of reliable and quality of power supply. Therefore, it is desirable to obtain power supply at high grid voltage of 220kV or 132kV or 66kV from stable grid substation and further transmission & distribution is done by Metro Authority itself. Accordingly, two receiving sub-stations (RSS) (66/33kV) are envisaged each for the E-W and the N-S corridors and these have been located in consultation with Bangalore Power Supply Authorities. The locations of these RSS are:

Corridor	Grid substation (input source)	Location of RSS of Metro Authority
E-W corridor	NGEF substation (66kV)	Baiyappanahalli depot
	REMCO substation (66kV)	Mysore Road Terminal
N-S Corridor	SRS Peenya sub-station (220/66kV)	Yeshwantapur Depot
	SARAKKI substation (66kV)	R.V. Road Terminal

33kV cables will be laid along the alignment on viaduct and in tunnels for catering to traction and auxiliary power requirements. Auxiliary sub-stations (33/.415kV) will be located in all the stations & depot for meeting auxiliary power requirements. The power supply system is planned to cater for 6-coach train operation at 150 seconds headway in year 2021. However, initially equipment will be installed to cater the expected power requirements during initial years of operation. The system can be augmented by way of adding main power transformer and traction transformer-rectifier sets as and when traffic builds up.

System of Traction

There are 3 standard and proven systems of traction for use in suburban and metro lines. These are 750V dc third rail, 1500V dc overhead catenary and 25kV ac overhead catenary system. All these three systems are already in use in India. Keeping in view the ultimate traffic requirements, difficulty in constructing large diameter tunnels in the city, aesthetics and other techno-

economic considerations, 750V dc third rail traction system is selected for Bangalore Metro.

750V dc third rail bottom current collection is envisaged from reliability and safety considerations with the use of composite aluminum steel third rail on main lines. Low carbon steel third rail is proposed for depots because of reduced current requirements. The third rail will be provided with suitable shrouds for safety of passengers as well as maintenance personnel. Life of composite and steel third rail is expected to be 25-30 years.

Traction Substations (33kV/750V dc)

Traction substations (33kV/750V dc) are proposed for feeding 750V dc power supply to the third rail. These traction substations (TSS) are proposed at alternate stations. The TSS alongwith Auxiliary Sub-Stations (ASS) will be located in station building itself at mezzanine or platform level inside a room. An additional traction substation will be located in each maintenance depot. The total requirement of TSS works out to be 10 and 8 for the E-W and the N-S corridors respectively.

Initially, 1x2.5MW transformer-rectifier set shall be provided in each TSS with space provisions for an additional set to be accommodated in future as and when trains composition is increased to 6 coach at 3 minutes headway. From the traction substations, 750V dc cables will be laid upto the third rail and return current cables will be connected to the running rails.

Supervisory Control and Data Acquisition (SCADA) system

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 66/33kV ac switchgear, transformers, 750V dc switchgear and associated electrical equipment.

Standby Diesel Generator (DG) sets

In the unlikely event of simultaneous tripping of all the four RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set at stations to cater to the essential services e.g. lift operation, essential lighting, ventilation of U/G stations, signal & telecom , fire fighting etc. Silent type of DG sets are proposed which have low noise levels and do not require separate room.

Electric Power Tariff

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of a metro system (about 25-35% of total annual working cost). Therefore, it is the key element for the financial viability of the Project. The annual energy consumption of the E-W & N-S corridors is assessed to be about 90 million units in initial years (2007), which will double by horizon year 2021. In addition to keeping the energy consumption to optimum, it is also necessary that the electric power tariff be kept at minimum in order to contain the O& M

costs. Therefore, the power tariff for Bangalore Metro should be at effective rate of purchase price (at 66kV voltage level) plus nominal administrative charges i.e. no profit no loss basis. This is expected to be in the range of Rs. 2.50-2.75 per unit. It is proposed that Government of Karnataka may take necessary steps to fix power tariff for Bangalore Metro at "No Profit No Loss" basis. Financial analysis has been carried out based on this tariff for the purpose of finalizing the DPR. Similar approach is being pursued for Delhi Metro.

0.9 S&T AND FARE COLLECTION SYSTEM

Train Control and Signalling System has been designed to meet a design headway of 150 sec. and shall comprise Continuous Automatic Train Control system with CAB-Signalling. Line side signals will be provided at all stations with points and crossings, which shall be used for the purpose of back up Signalling. The system shall be 'Distance-to-Target' based on fixed block type using coded Audio Frequency Track Circuits. All the stations with points and crossings shall be provided with independent SSI with facility to operate these points and crossings locally as well as being Centrally Controlled from the OCC. The CAB-borne and wayside signalling equipment shall be designed with sufficient redundancy so as to meet the desired reliability and availability requirements. The mimic panel for this corridor shall be housed in the OCC at Majestic. The Depot shall be provided with an independent SSI.

Telecommunication System shall comprise various sub-systems namely Fiber Optic transmission system (FOTS), Telephone, Radio, Public address, Close Circuit TV and Public Information display system etc. The FOTS shall have armoured optical fiber cable with path diversity. The equipment proposed shall be of synchronous digital hierarchy (SDH) in 1+1 configuration with add/drop multiplexer at enroute stations to provide reliable backbone link. It is proposed to provide ISDN – EPABX system to be integrated with other telephone systems with access to PSTN and interface to radio system. The proposed radio system shall support both train radio and hand held portable sets for communication with central control. Microprocessor-based Network Management System covering radio / optical fiber based communication and telephone exchange system shall be provided.

For trouble free and efficient ticketing and passenger control, computerised Automatic Fare Collection (AFC) System has been proposed. The base AFC system shall make use of "Contactless Smart Card Tickets" for multiple journeys and contact less smart token for single journey, working with multiple operators. The AFC system shall have equipment located at OCC and stations. The ticket gates are proposed to have a handling capacity of 45 passengers per minute and can be reversible type.

Initially Booking office operated machines (BOMs) are proposed but provision for Passenger operated machines (POMs) has been kept at stations.

0.10 MAINTENANCE DEPOT

On the East - West corridor a maintenance depot along with full workshop facilities has been proposed at Baiyappanahalli, adjacent to the Eastern terminal station. The area of the Depot is about 20 Hectares. The site has a

road approach from the Old Madras road. A test track of 948 m length has been proposed in the Depot. A washing plant is also proposed here.

Holding capacity of the Depot has been planned to be 16 rakes of 6 coach each. Daily tests and checks shall be done at stabling sidings. 3 day, 15 day and 3 monthly inspection shall be done inside the Inspection Shed. The facilities shall be provided in phases and augmented as the train frequency and formation increases due to growth in traffic. Overhauling of the rakes is also planned at this depot.

On the North - South corridor a smaller depot is proposed at Yeshwantapur in an area of about 12 hectares. The Depot is proposed at elevated level and will have stabling for 14 rakes of 6 coach each. A washing plant is also provided. The inspection bays for normal inspection and workshop for repairs is planned at this Depot for independent functioning. The rakes from the North - South corridor are required to be taken to Baiyappanahalli depot for overhauling.

0.11 OTHER ENGINEERING WORKS

Geo Technical Investigation

Geotechnical investigations were carried out along both the corridors upto a depth of 30 m in soil and 3 to 4 m in hard rock. Soil and rock samples were collected and tested in laboratory.

The top layer of soil is generally reddish silty sand with clay. The layer is medium dense. Below this, is a layer of soft rock and a layer of hard rock.

The underground corridors are generally passing through a layer of dense sandy clay or soft rock. Only on the Post Office Road hard rock is encountered which will be mostly constructed through cut and cover method being a station area.

For the elevated section shallow foundation on soft rock and pile foundation upto 1.2 m dia are recommended. The bearing capacity of soil is not likely to cause any problem for the foundations.

Utilities

The proposed Metro alignment is passing along major arterial roads of the city road network, which are serving Institutional, commercial and residential areas. A large number of surface and sub-surface utility services viz. sewers, water mains, storm water drains, telephone cables, electric poles, traffic signals etc. are existing along the proposed alignment. Details of the existing utility services along the proposed alignment have been collected from the concerned authorities, i.e. BMC, BWSSB, BSNL, Bangalore Electric Supply and Distribution authorities, Reliance and Tata Telecom, etc. The affected portions of the services with reference to the proposed alignment were identified and temporary diversion & relocation proposals of the affected services have been indicated.

One of the major utility requiring shifting is a 66 KV substation on the Mysore road at the terminal station. This sub station can be relocated on the opposite side of the road. Along with the sub station the overhead distribution power line is to be converted to cable.

Land Requirement

Since land is a scarce commodity especially in metropolitan areas, every effort has been made to keep land requirement to the barest minimum and acquisition of private property is minimal. Land is mainly required for Depots and route alignment on sharp bends, station buildings, platforms, entry/exit structures, traffic integration, power sub-stations, ventilation shafts, administrative buildings and temporary construction depots / work sites etc.

Land requirement on the East - West corridor is about 27.05 hectares out which 23.82 hectares belongs to government and public sector organisations while 3.23 hectare is private land.

On the North South corridor the total land requirement is 18.19 hectares out of which 2.57 hectares belongs to Government and public sector and 15.62 hectares on private land. The major share of private land on the North – South corridor is about 13.43 hectares for the Depot at Yeshwantapur.

The estimated land cost is Rs. 360 crores.

Rehabilitation & Resettlement

The project involves displacement of about 260 residences, 89 shops, 9 offices,6 small factories and a number of miscellaneous private and Government properties. Most of the affected houses are in Subhash Nagar area and Police quarters in Ulsoor area. The other affected residential areas are on Swami Vivekanand Road, station locations and various junctions where sharp bends are provided. The commercial areas to be displaced are generally from Swami Vivekanand road.
The displaced persons are to be relocated in nearby areas, which are identified and detailed out in the Report.

Property Development

Like most rail-based mass urban transport systems world over, the proposed Metro corridors are also not financially viable, though they are economically very attractive. Therefore, in order to finance part cost of the project construction, it is proposed to develop and exploit the potential of commercial utilisation of real estate along / close to the proposed alignment on land. Demand for space in insurance, finance, hospitality, information technology, recreation, leisure and residential sectors is expected to increase substantially in the near future. With the construction of Metro corridors, demand for other consumer sectors is also expected to go up. In all, eight plots (Government & private owned) have been identified for property development and commercial utilisation.
However for commercial development with good return it is necessary to have Government land or land at much cheaper rate. Unfortunately such land is very scarce along the two corridors.

Hence it is proposed to carry out commercial development along with the stations which are located 'off' the road and at the two Depots. At Majestic, where the office of the proposed SPV and Operation Control Center are proposed, space for offices can be provided on 3 to 4 floors.
It is felt that significant funds cannot be generated through property development during construction period but revenues to the extent of 10% of fare box collection will be raised through property development and advertisements during operation.

0.12 ENVIRONMENTAL IMPACT ASSESSMENT

A detailed Environmental Impact Assessment Study has been carried out along the proposed alignment. As a part of this Study, comprehensive environmental baseline data was collected. Both positive and negative impacts of the project were assessed in detail. An important environmental consideration of this project is that neither any forest area nor any plants / trees of endangered species exist along the proposed alignment, though few Jhuggi clusters / unauthorised constructions and residential / commercial properties are affected. To minimise the negative environmental impacts, a comprehensive Environment Management Plan has also been drawn up, both for construction and operational phases, outlining necessary remedial measures. Department of Environmental Science, Bangalore University provided consultancy studies for Environmental Impact Assessment Studies and Social Impact Assessment Studies.

0.13 COST ESTIMATES

Preliminary Cost Estimates for the two corridors have been prepared at March 2003 prices. The estimated cost at April, 2003 prices is Rs. 3970 crores including land cost. The completion cost with project completion in the year 2007 is Rs. 4379 crores including escalation. Interest on loan during construction (IDC) works out Rs. 610 Crores. Thus including escalation and IDC completion cost works out to Rs. 4989 crores.

ABSTRACT CAPITAL COST ESTIMATE FOR BANGALORE METRO

(COSTS AT APRIL, 2003 PRICE LEVEL)

S.No.	Description	Amount * (Rs. in Crores)		
		E - W Corridor	N –S Corridor	
1. Land	**Land**	170.00	190.00	**360.00**
2.	**Civil Engineering Works**			
2.1	Alignment and formation			
2.1.1	Underground Section	332.50	294.5	627.00
2.1.2	Elevated	235.20	190.4	425.60
2.1.3	Under ground stations	168.00	126.0	294.00
2.1.4	Utilities (Civil work) Environmental Protection, Rehabilitation & resettlement.	30.00	20.00	50.00
2.2	Station Buildings (elevated and at-grade).	135.00	105.00	240.00
2.3	Permanent Way	97.00	79.00	176.00
2.4	OCC & Administrative building	27.00	-	27
	Sub Total (Item 2)			**1839.60**
3.	**Electrical works**			
3.1	Traction & Power Supply	170.22	148.03	318.25
3.2 VAC	VAC	40.40	30.27	70.67
	Sub Total (Item 3)			**388.92**
4.	**S & T works**			
4.1	Signalling & Telecommunication including cable diversions	140.00	108.00	248.00
4.2	AFC installations at stations	35.00	27.22	62.22
	Sub Total (Item 4)			**310.22**
5.	**Depots**	84.00	50.00	**134.00**
6.	**Rolling Stock (in 2007)**	346.50	297.00	**643.50**
7.	**GRAND TOTAL**	**2010.82**	**1665.42**	**3676.24**
8.	**General charges @ 8 % inclusive of contingency @ 3%**			**294.10**
	Grand total:			**3970.34**
Say	**Rs. 3970 Crores**			

* The above cost estimate excludes the element of taxes and duties.

0.14 IMPLEMENTATION STRATEGY and PROJECT IMPLEMENTATION

On approval of Detailed Project Report immediate action is to be taken for the following:

a) Signing of MOU between Karnataka Government and the Central Government (MOUD)

b) Arranging institutional setup for implementation of the project.

c) Providing legal cover for the construction as well as operation and maintenance stages of the project.

Institutional Arrangement

It is recommended to form an SPV for implementation of the project. As the SPV needs to be vested with adequate powers to implement and operate the system, it is recommended to form the SPV on the lines of Delhi Metro Rail Corporation (DMRC). The SPV can be named as Bangalore Metro Rail Corporation (BMRC). It is proposed that the State Government and the Central Government, each will contribute 20% of the project cost as equity and also equally share the land cost as an interest free subordinate loan to the SPV. As the SPV formed on the lines of DMRC will have equal equity from Central and State Governments, the number of Directors from the State and the Central Government will also be equal. While the Managing Director will be a nominee of the State Government, the Chairman should be the Secretary, Ministry of Urban Development and Poverty Alleviation of the Central Government. The Board of Directors (BOD) are to be vested with full powers to implement the project with adequate delegation of power to the Managing Director for day to day working.

It is also recommended that a 'High Power Committee' headed by Chief Secretary, Karnataka Government and comprising secretaries of the concerned departments of the State Government and heads of civic agencies be constituted to sort out the problems connected with implementation of the project.
The Group of Ministers and Empowered committee set up for Delhi Metro Project by the Central Government could also continue for the Bangalore Metro project for granting clearances on behalf of the Central Government.

LEGAL FRAME WORK

Construction as well as operation of a Metro system needs a legal framework due to involvement of public safety and other commercial and operational matters.. The existing legislation, viz. Metro Railways (Construction of Works) Act, 1978 is not adequate as it covers only the construction stage of Metro Railways and cannot be applied to Bangalore Metro. The legislation for Delhi Metro covers only the O & M stage and can not be made applicable to Bangalore Metro. As the construction of Bangalore Metro is proposed to start during 2003-2004, there is no time to enact a new legislation for construction work. Hence it is recommended to amend the 'Metro Railways (construction of works) Act' 1978 and make it applicable to Bangalore (and also other million plus population cities). However sufficient time is available for enactment of a

new comprehensive legislation to cover both the construction and operation & maintenance stages of Metro Railway.

IMPLEMENTATION PROGRAMME

An implementation programme indicating the completion of various segments of the two corridors has been prepared showing the project construction schedule. The sequence of opening of corridors has been is as follows:

a)	Start of Construction work	-	Oct 2003
b)	Baiyappanahalli - Cricket Stadium section	-	Oct 2006
c)	Yeshwantapur - Swastik section	-	Dec 2006
d)	Underground section (both corridors)	-	Aug 2007
e)	City Railway station - Mysore road	-	Sep 2007
f)	City Market - R V road	-	Dec 2007

These targets can be achieved if action to set up the SPV is taken in 3 months and the work for detail design and tendering is started by July 2003.

Since, this project involves different type of constructions, viz. underground, at-grade and elevated besides Depot construction at 2 locations, construction planning needs to be taken up in great detail before hand so as to ensure proper and timely completion of the project.

0.15 ECONOMIC ANALYSIS

The proposed system will provide a variety of benefits to the city and society, viz. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. Economic analysis has been carried out for the proposed Metro network by comparing **"with"** and **"without"** project scenario. The **'with'** project scenario takes into account, estimated total costs that the local economy would be called upon to bear. The **'without'** project scenario envisages a situation wherein the existing infrastructure continues to be utilized taking into account increased estimated costs due to higher projected traffic.

The benefits accruing as a result of project implementation are

- savings in vehicle operating cost
- reduction in congestion
- saving in passenger travel time
- reduced pollution and fuel consumption.

The cost and benefit streams arising under the above situations have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices.

The Economic Internal Rate of Return **(EIRR)** for Bangalore Metro (phase –I) has been worked out using Discounted Cash Flow technique to the net benefit stream at economic prices and its value is estimated as **22.3 % .**

0.16 FINANCIAL ANALYSIS

The financial analysis for the project has been worked out taking into consideration the completion cost, operation and maintenance cost as well as the additional expenditure to be incurred in coming years for additional Rolling Stock and augmentation of power supply system. Fare structure has been suggested with a fare of Rs. 4 for distance upto 2 km, Rs. 5 for distance between 2 to 6 km, Rs. 7 between 6 to 12 km and Rs. 9 beyond 12 km distance from the year 2007. These have been proposed for escalation @ 4% per year. In addition earning is assumed @ 10 % of the fare box revenue from advertisement and commercial developments. The comparative fare for Buses is given below:

Distance	Proposed fare for Metro(@ 2007 prices)	Bus (present)	Pushpak (present)
Upto 2 Km.	Rs.4	Rs.2	Rs.3
2-6	Rs.5	Rs.3-4	Rs.5
6-12	Rs.7	Rs.5	Rs.7-8
more than 12	Rs.9	Rs.5	Rs.8

Based on this fare structure, FIRR for the project works out as **3.16 %.** For preparation of fare policy, National Council of Applied Economic Research (NCAER) was engaged as sub consultants.

0.17 FINANCING PLAN

For developing Financing Plan for this project, consultancy was obtained from M/s ICICI. It has been recommended that 40% of the project cost will be shared equally by the State Government and the Central Government as Equity to the SPV. Land cost, which works out to 8% of the project cost, will be provided by the Central Government and the State Government in equal proportion as interest free subordinate debt. The balance 52% of the project cost will be raised by loan from the domestic market. Based on the current price, the Total project cost will be about Rs.3970 crore without Escalation and IDC. The Grand total cost with Escalation and IDC comes out about Rs. 4989 crore.

0.18 CONCLUSIONS AND RECOMMENDATIONS

For successful implementation of any metro project, which by its very nature is highly technical and complex, huge in size and to be executed in difficult urban environments, political will and commitment is necessary. Decisions are to be taken fast and the implementing agency must have the required work culture, commitment to targets, safety, quality and cost consciousness.

Metro projects are highly capital intensive. On account of the high costs involved and the need to maintain a fare structure within the affordable reach of ordinary citizens, metro projects are not ordinarily financially viable. But considering the overwhelming economic gains to the society and the fact that cities with population of more than five million cannot just survive without an

efficient metro system, it is strongly recommend that the Bangalore Metro system be taken up for implementation in the financial year 2003-2004 itself.

This DPR is for first phase only. Bangalore being one of the fastest growing urban agglomeration of the country will need a bigger metro network. The two corridors proposed in phase I will require to be extended and two more corridors will need to be provided within the next 10 years. It is recommended that the State Government should get a Master Plan prepared for Bangalore Metro so that all future constructions can be taken up as per this Master Plan.

Based on the details as furnished in the Detailed Project Report the project is to be implemented on priority basis.

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